The Late Quaternary Sediments and Fossil Vertebrate Fauna from Cathedral Cave, Wellington Caves, New South Wales

LYNDALL DAWSON AND M.L. AUGEE

Biological Science, University of New South Wales, Sydney, NSW 2052

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Excavation of the floor of Cathedral Cave, Wellington Caves, was undertaken between 1982 and 1986. Three major phases of deposition are recognised, representing the end of the last interglacial (Phase 1), the last glacial maximum (Phase 2) and a Holocene phase (Phase 3). Radiocarbon dating of small amounts of charcoal in Phase 1 gave dates ranging from 33,800 BP to 21,000 BP, while dates of 2,590 BP and 2,950 BP were obtained from Phase 3 sediments.

Within these Phases stratigraphic, sedimentological and taphonomic changes are apparent. Phase 1 has the characteristics of an attritional entrance facies deposit. Large taxa (>1.5 kg body weight) are represented by juveniles only, except for scavengers and carnivores, suggesting a pitfall trap. The abundance of small mammals is consistent with their accumulation due to owls and the Ghost Bat, which is present in the bottom 1.25 m of the deposit. In Phase 2 a high degree of disturbance is suggested by the inclusion of large limestone boulders and rocks and the highly fragmented nature of the bone. Two distinct heavily indurated 'floors' dip toward the south-east and suggest entry of the sediments from a point in the roof of the cave co-incident with the apex of the present 'altar' formation. The sediments of Phase 3 are not indurated and contain no large boulders or bone fragments, larger species being represented by isolated teeth only. The entrance source of Phase 3 sediments is unknown.

At least 38 marsupial taxa have been identified of which 10 are extinct. Of the remaining 28 extant marsupial taxa only 9 may still occur west of the Great Dividing Range today. Of the non-marsupial taxa rodents are most abundant. Microchiropteran bats are represented in several strata, as are reptiles and small birds. Pleistocene 'megafauna' taxa are represented in Phase 1 and Phase 2. 'Megafaunal' species include *Macropus (Osphranter) altus, M. (M.) titan, M. (M.) ferragus, M. (Notamacropus)* n. sp., *Protemnodon* sp., *Simosthenurus oreas*, and *Thylacoleo carnifex.*

The fauna of medium and smaller sized mammals exhibits disharmonious assemblages typical of other late Pleistocene/Holocene faunas of eastern and south-eastern Australia. The presence of the Ghost Bat, *Macroderma gigas*, in Phase 1 suggests a suitable configuration of the cave and cave entrance at that time, and a warmer, wetter climate than Phase 2. Fauna of Phase 3 lacks extinct species and is representative of conditions which existed at the time of first European settlement of the Wellington region.

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INTRODUCTION

The Wellington Caves, located 6 km south of Wellington on the western slopes of the Great Dividing Range in New South Wales, have been renown, since their first discovery in 1830, as a rich source of fossil bones, including many taxa of extinct marsupials. The history of their exploration and excavation has been reviewed most recently by Dawson (1985) and Osborne (1991). Descriptions of the caves complex, the associated sediments and stratigraphy have been published by Frank (1971), Francis (1973) and Osborne (1983).

The complex consists of several natural chambers and man-made tunnels which have been excavated from the sediments which fill much of the cave system. Over a period of more than 150 years, fossil bones have been collected from Mitchell Cave,

Figure 1. Map of the floor of Cathedral Cave, Wellington Caves, indicating the position of the University of New South Wales' excavation (1982–1986).

Cathedral Cave, Big Sink, Bone Cave and the Phosphate Mines. It had previously been assumed that all the sediments in the caves were of Pleistocene age because of the predominance in museum collections of the bones of extinct marsupial megafaunal taxa. However, the stratigraphic studies of Frank (1971) and Osborne (1983) suggested that the sediments may possibly range in age from Miocene to late Pleistocene.

To test this hypothesis, a team from the School of Zoology, University of New South Wales, commenced stratigraphically controlled collection of bones from several of the caves. Between 1982 and 1986 bones were collected from Big Sink, the Phosphate Mines, Bone Cave and Cathedral Cave. The first results of this study have indicated an early to mid-Pliocene age for the deposits in the Big Sink, hypothesised by Osborne (1983) to be the oldest stratigraphic units in the complex (Hand et al. 1988). The present paper continues this study and reports on the sediments and fauna from the floor of the Cathedral Cave.

DESCRIPTION OF CATHEDRAL CAVE

The Cathedral Cave is the largest of the natural caves in the Wellington Caves complex. The cave (Fig. 1) consists of a steeply sloping entrance passage which extends for about 40 metres before expanding into a huge main chamber with dimensions of 45 m long, 20–25 m wide with a domed roof approximately 14 m maximum height. This chamber now has a nearly level compact earth floor, which is approximately 20 m below the ground surface. At the northern-most end of the chamber a huge 'stalagmite' reaches from floor to ceiling. The cave derives its name from the resemblance of this flowstone covered pillar to a cathedral altar.

The chamber has been formed by nothephreatic solution in massive limestone of the Devonian Garra Formation (Osborne 1983). The walls and roof of the chamber are largely devoid of speleothems. The chamber has been formed along a fault between thinly bedded limestone which forms much of the roof and eastern walls, and unbedded massive limestone forming the western roof and walls. The 'altar' occurs on this fault line. Immediately north of the 'altar' there is a vertical drop of approximately 3.5 m to the floor of a second narrower chamber. This floor extends horizontally for approximately 30 m to another vertical drop of 6–7 m terminating in a pond of water. The level of water in this pond varies with rainfall and the flow in the nearby Bell River. During a flood in 1956 the water rose to a level 1 m deep throughout the second chamber (i.e. only about 2.5 m below the floor of the main chamber).

The Cathedral Cave (then known as "the Great Cave") was described and illustrated by Sir Thomas Mitchell, who first entered this cave and surveyed it in 1830 (Mitchell 1838). Mitchell discovered some fossil bones in Cathedral Cave in 1830, but these were considered insignificant in comparison to his discoveries in the nearby "Breccia Cave". Prior to 1881 extensive bone collections of great significance were made from the "Breccia Cave" (now known as Mitchell's Cave) (Dawson 1985). However, there is no record of any collection from Cathedral Cave during that period.

In 1881 at least two shafts were dug in the earthen floor of the main chamber of Cathedral Cave during an exploratory expedition undertaken by the Australian Museum under the direction of the Curator, E. P. Ramsay. The location and depth of these shafts is indicated by Ramsay (1882), the most productive excavation being Shaft No 2, which was sunk near the 'altar' and described as follows:

'At No 2 shaft, which we sunk to the depth of 25 feet, many important bones have been found, and the different floors we went through show that these bones have been washed in at different periods. In the last layer, the red mud-like breccia which characterised this shaft (at present) has become more sandy, the bones being more perfect here and less worn' (Ramsay 1882, p.34).

This tantalising description provided much of the incentive needed to sustain the most recent excavation of the Cathedral Cave floor, the results of which are described in this paper.

MATERIALS AND METHODS

The excavation

The position of the UNSW pit, between the "altar" and the south wall of the main chamber is indicated in Fig. 1. A site close to the location of Ramsay's "No. 2 shaft" was preferred because of its promised depth and productivity. Care was taken to avoid the exact location of the previous shaft. The fact that the cave was continuously in use by large groups of tourists further limited the choice of sites for the excavation.

Surface dimensions of the pit were 2.0 m x 1.0 m, with the long axis extending away from the "altar" in a SSE direction. The northernmost edge of the pit was approximately 1 m from the outer rim of the base of the "altar", which is delineated by concen-

tric ridges of flowstone. Surveyed co-ordinates of the pit are Easting 294 294.7 Northing 1 289 237.1 Height 322.6 (Integrated Survey Grid [ISG] of NSW).

Sediments were excavated by hand in 'spits', which were of variable depth, ranging from 10 to 20 cm, depending on the nature of the sediment encountered. Each spit was further divided into 8 horizontal grid segments, labelled A-H. The final depth of the excavation was approximately 7.25 m from the cave floor surface. All material was bagged and labelled before being stored in the cave, or removed from the cave for further treatment, either locally or at the University of New South Wales.

Treatment of the sediments consisted of first drying them, then screen washing (flyscreen) with water. Residual lumps of sediment which were insoluble in water were treated further with dilute acetic acid. However, there was generally poor breakdown of the clay-rich breccia in acid. As far as possible all bone was retrieved and stored for further analysis. Other inclusions such as charcoal, gravels, and limestone pieces were also retained for future examination.

During the excavation samples were collected for detailed sedimentary analysis. Unfortunately most of these samples were inadvertently destroyed.

Analysis of bone

After screen washing and treatment of the sediments, all bone was collected and labelled according to the spit and grid sector of origin. Only teeth and jaws have been used to identify the taxa present in the deposit. The absolute number of individuals per stratigraphic unit could not be used for comparison between units because each unit represents an unknown (different) volume of sediment. In order to compare the relative abundance of various mammalian taxa, the minimum number of individuals (MNI) and the percentage abundance of each taxon was calculated for each stratigraphic unit. The estimate of minimum number of individuals was based on a count of identifiable right and left dentaries and maxillae. The most numerous element was taken as the MNI. Where a taxon was represented by a few isolated teeth only, it was scored as MNI = 1, except in the case of the peramelids (bandicoots),which were frequently represented by isolated molar teeth. These teeth were identified by position in the tooth row (e.g. LM^4, RM_2) and the most numerous element was taken as the MNI. The percent abundance of a taxon in each unit was calculated by the formula MNI /Total MNI per unit X 100. Non-mammalian taxa were not included in this analysis.

Dental nomenclature follows Luckett (1993). All specimens are registered in the collections of the Australian Museum, Sydney.

Abbreviations: AM = Australian Museum, QM = Queensland Museum, L = length, AW = anterior width, PW = posterior width, mm = millimetres.

RESULTS

Stratigraphy

The present floor of Cathedral Cave is nearly horizontal and has been beaten to a smooth hard surface by tourists over many years. At the site of the excavation the floor was somewhat irregular and sloped slightly away from the altar. The top metre of soil showed evidence of extensive disturbance. Fragments of bottle glass, sawn timber, metal, and even a piece of gramophone record were encountered in Spits 1–3. There was no further evidence of disturbance of the sediments by man below Spit 4, approximately one metre below the present floor. That the sediments beneath Spit 4 were undisturbed was supported by the presence in Spit 5 of a thin discontinuous layer of flowstone, no more than 2 cm thick, below which an orange cemented sediment rich in small bone fragments was encountered.

Over a period of approximately four years the Cathedral Cave excavation was continued to a final depth of 7.25 m below the present floor of the cave. Throughout the pit the sedimentary matrix consisted predominantly of heavy red clay. Inclusions varied in size from large limestone boulders (up to 30 cm in diameter) to gravels, and included both jagged rock fragments and smooth river pebbles. After consideration of the nature of the stratigraphy of the deposit, it became apparent that analysis of 10 cm spits was unwarranted, so samples were pooled for 50 cm intervals for the purpose of faunal analysis.

TABLE 1

Stratigraphic description of excavation in floor of Cathedral Cave, Wellington Caves.

Depth (m) at base of unit	Spit groups (inclusive)	Description
Phase 3 −1.5	4–5	Matrix of heavy red clay mottled with grey loamy textured silt, containing gravels and limestone nodules of varying size plus occasional small pieces of flowstone. Residue after washing comprised 30–40% original volume of insoluble material including bone and calcified clay aggregates. Bone: low concentration of small fragments of bone, max. fragment length approx 2cm.
Phase 3 −2.0	6–10	Matrix and inclusions as above. Lens of charcoal in spits 6 and 7 gave C^{14} date of 2,950 ± 80 BP. Bone: as above, larger taxa represented by isolated teeth only.
Phase 3 −2.5	11–15	Matrix and inclusions as above. Large boulder approx. 20 cm diameter in spits 11–12. At spits 13–14 there was a hardened 'floor' 10 cm thick composed of indurated clay and flowstone, dipping south at approxmiately 20°. A small circular area rich in charcoal occurred immediately below this 'floor' and gave a C^{14} date of 2540±80 BP. Bone: As above, max. fragment length approx. 3 cm.
Phase 3 −3.0	16–19	Matrix of heavy red clay, less insoluable residue than overlying strata including gravels and limestone fragments. Bone: As above, max. fragment length approx. 4 cm.
Phase 2 −3.5	20–23	Zone comprises a hard 'floor' approximately 20 cm thick extending the entire length of the pit, dipping south at approximately 20^{o} . This consists of heavily cemented clay with inclusions of limestone boulders and fragments, flowstone and bone breccia Bone: Relatively high proportion of bone representing both large and small taxa. Large bone variably preserved, some weathered prior to deposition, fragmented. Max. fragment length approx 23 cm. Largest taxa represented by juvenile individuals.
Phase 2 −4.0	24–28	Matrix of zone immediately below the 'floor' comprised unconsolidated red clay with few large inclusions. At north-west corner of spits 26 A–27A encountered a limestone boulder >30 cm in diameter with crushed and broken bone cemented to it. Another very large boulder in 28C. Spit 26 represents top of a layer of 'rubble' approx 30 cm deep dipping to the south as above, but less heavily indurated than 'floor' described above. Bone: low concentration of small and larger bone fragments which are thinly encrusted with calcite. Largest taxa represented by juvenile individuals. Max. bone length = 14cm.
Phase 2 −4.5	29–33	Matrix of heavy red clay, residue after washing comprised from 90% (at top of zone) to 30% (toward base of the zone) of original volume as insoluble calcite nodules and limestone pieces. Bone: Relatively low bone content, small jaws and fragments only, thinly encrusted with calcite. Max. bone length = 5 cm.

Phase 2 −5.0	34–38	Matrix of heavy red clay, residue after washing comprised 30–50% original volume of small calcite nodules and flakes. Spit 36 A (nth end) contained thin indurated layer including much small gravel overlying a thin layer of blackened small bone. Spit 36B encountered top of a limestone boulder approx. 30 cm diameter. Bone: Relatively high concentration of large and small bone with largest pieces approx. 12 cm long; partial macropodid cranium 8 x 11 cm. Bone encrusted with red calcite.
Phase 1 −5.5 −5.5	39–42	Matrix of sandy red clay, gravels and occasional large pieces of limestone, residue after washing containing calcite nodules and flakes. Pooled sample of charcoal from spit 40 gave a C^{14} date of 21,400±700 BP Bone: Very rich in bone, many larger bones (including robust femur 24 cm long) , also rich in bones of small taxa. Bone reddish cream in colour, thinly encrusted in calcite, not abraded or chewed.
Phase 1 −6.0	43–45	Thin calcite layer on top of spit 43 at north end of pit, petering out towards south. Matrix of sandy reddish clay with higher gravel and bone content. Residue after washing contains many flat grey ?calcite flakes. Bone: Relatively high content of bones of small and larger taxa. Bone well preserved, cream-brown in colour, no calcite encrustation. Largest bone fragment 16 cm long. Associated skeletal elements present. Some bone appears gnawed.
Phase 1 −6.5	46–50	Matrix of reddish clay with high proportion of sand and gravels. No evidence of dipping strata. Pooled samples of charcoal from Spit 46 gave C^{14} date of 21,350 ±1,700 BP. Pooled samples of charcoal from Spit 50 gave C^{14} date of 26,800±2000 BP. Bone: Relatively low bone content, washed clean with water, lacking calcite encrustation. Bones represent mostly small taxa with larger taxa represented by isolated teeth only. Largest bone fragment 7 cm long. Some bone slightly gnawed.
Phase 1 −7.0	51–54	Spit 51 as above. Spits 52 and 53 comprised of grey friable matrix. Thin hard calcite layer in spit 54, red matrix below this. Charcoal from Spits 51 and 52 gave C^{14} dates of 33,800±2000 BP and 32,500±2100 BP, respectively. Bone: Extremely rich in large and small bone fragments, longest approx. 17 cm; associated elements present; rich in bones of small taxa. Bone washed clean in water; colour mottled grey, no calcite encrustation, larger bone not gnawed or abraded.
Phase 1 −7.5	55–57	Matrix red sandy clay, inclusions wash clean in water, not indurated, but contained many flat grey 'flakes' of rock (?calcite). Many large limestone boulders encountered below spit 55. Bone: Relatively high content of creamy coloured bone, washed clean in water, lacking calcite encrustation; large species represented by isolated teeth and fragmented bone with highly abraded (? gnawed) ends; largest fragment approx 9 cm long. No associated elements.

Detailed description of the sediments is provided in Table 1. Stratification within the sediments was indicated by variations in degree of induration and cementing of layers to form successive "floors" throughout the deposit. As the excavation proceeded several hardened "floors" of varying thickness were encountered as described in Table 1. Above Spits 30–33 (-4.25 to -4.5 m) these "floors" dip at a consistent angle of approximately 20 degrees from the north edge of the pit towards the south, i.e. slope away from the base of the "altar", consistent with the hypothesis that they form an extension of the base of a cone of sediment with its apex under the existing stalagmite called the "altar". Below 4.5 m the stratification is nearly horizontal.

The following factors have been considered in formulating a hypothetical interpretation of the history of this deposit:

- the sequence and direction of slope of hardened 'floors' and flowstone layers
- degree of induration of the sediments
- the preservation of bone, including size, colour, fragmentation, association of elements, presence of juveniles etc.
- the nature of inclusions (other than bone) in the sediments
- the information from C^{14} dating of charcoal

Examination of the data presented in Table 1 has indicated three main phases in the deposit. These are described and justified below.

Phase 1

This is the oldest phase of deposition, and extends from the base of the pit (7.5 m) to approximately 5.0 m below the surface (Units 55–57 to Unit 39–42, inclusive). The upper boundary is not delimited by any definite demarcation line; in fact Spit 38 and Unit 39–42 represents a transition zone. However, Phase 1 has several characteristics which define it:

- sediments are approximately horizontal
- predominantly more sandy/gravelly sediments
- much less calcification / induration of sediments than higher levels — almost completely soluble in water
- bone well preserved, less fragmented, including some associated elements and intact skeletal elements of larger taxa
- large taxa represented mainly by juveniles
- fauna contains extinct taxa and "megafauna"

Phase 2

The middle phase of deposition extends from approximately 5.0 m to approximately 3.0 m below the surface (Units 34–38 to 20–23 inclusive). The upper boundary of this phase is demarcated by heavily indurated rubble 'floor' approximately 20 cm thick. Characteristics defining Phase 2 are:

- red clay, generally heavily indurated, does not break down readily in water
- large number of boulder-sized inclusions and many smaller rock
- strata dip at approximately 20° from north to south
- large bones highly fragmented, some weathered prior to deposition
- large taxa represented by small jaw fragments or isolated teeth only
- large taxa mainly represented by juveniles.
- fauna contains extinct taxa and "megafauna"

Phase 3

The most recent phase of deposition is represented from -3.0 m to the surface (the top one metre being disturbed since European settlement). Characteristics of Phase 3 are:

- red clay, variably indurated, mostly breaks down in water
- inclusions consist mainly of gravels, small limestone nodules and small pieces

of flowstone.

- low bone concentration.
- bone fragments small, large taxa represented by isolated teeth only
- little evidence of stratification — some thin flowstone sheets
- no extinct species represented

TABLE 2

Radiocarbon dates obtained from charcoal excavated from the floor of Cathedral Cave, Wellington Caves. Asterisk indicates pooled samples. Depths represent depth below present cave floor.

Sample no.	Spit	Depth	Age (yrs BP)
SUA 2097	Spit 6	1.6 m	2950 ± 80
SUA 2098	Spit 14	2.7 m	2590 ± 80
ANU 4480	Spit 39 *	5.1 m	14,300 ± 730
ANU 4479	Spit 40 *	5.2 m	21,400 ± 700
ANU 4478	Spit 44 *	5.8 m	11,900 ± 790
ANU 5323	Spit 46	6.1 m	21,350 ± 1700
ANU 5324	Spit 47 *	6.2 m	28,000 ± 1100
ANU 5325	Spit 49	6.4 m	23,700 ± 1400
ANU 5326	Spit 50 *	6.5 m	26,800 ± 1100
ANU 5327	Spit 51	6.6 m	33,800 ± 2000
ANU 5328	Spit 52	6.7 m	32,500 ± 2100

Radiocarbon dating

Charcoal was rare in the Cathedral Cave deposits, but small samples of charcoal were recovered during the excavation and while screen washing. These were collected in sealed plastic bags and submitted for radiocarbon dating. The results are presented in Table 2. The first two samples (Spits 6 and 14) were submitted to the Radiocarbon Laboratory at the University of Sydney (SUA) in 1984. A further 9 samples (from Spits 39 to 52) were submitted to the Radiocarbon Dating laboratory, Research School of Pacific Studies, Australian National University (ANU), in 1985 and 1986. In several of the spits it was necessary to pool small samples of charcoal to obtain a quantity large enough for dating. Dates derived from pooled samples are indicated with an asterisk in Table 2.

The irregularities apparent in the sequence of the dates (Table 2) may be due to a variety of factors, including contamination during handling and pretreatment of small pooled samples of charcoal, lateral facies changes and variable transportation of different elements (Archer 1974, Osborne 1984). The date for Spit 44 (ANU 4478) is most likely to be anomalous and due to younger organic contamination during pretreatment (J. Head, ANU Radiocarbon Dating Laboratory, pers. comm. 1985).

The C^{14} dates presented in Table 2 provide an indication of the probable time span involved in this deposit, from approximately 34,000 BP (the minimum age of the lowest sediments) to approximately 2,500 BP for the undisturbed sediments at the top of the deposit. While there are several inconsistencies in the sequence of the dates throughout the column, the general trend of the dates indicates that the lower levels of the deposit are older than the higher levels, i.e. that there is no major stratigraphic reversal present.

The fauna

Bone fragments were present throughout the deposit (Table 1). The preservation of the bone varied enormously, ranging from very weathered bone, some crushed bone, some heavily mineralised well preserved elements and some clean, lightly mineralised bone. Generally the larger bones were very fragmented and, with few exceptions, large taxa were represented by small jaw fragments only. No intact jaws or associated skeletal elements were encountered until more than 5 m below the surface, after which depth the bone was generally better preserved.

Teeth and jaws referable to marsupial taxa have been identified to species level where possible. Specific identification of most other non-marsupial remains has not been attempted, with the exception of some of the rodents, the Ghost Bat, *Macroderma gigas*, and the identification of snail shells (Mollusca).

The fauna of the Cathedral Cave deposit is summarised in Table 3, which indicates the presence/absence data for taxa at each stratigraphic level. At least 38 marsupial taxa have been identified in the deposit, of which 10 are extinct, and one, *Sarcophilus harrisii*, is now confined to Tasmania. Of the remaining 27 extant marsupial taxa only 9 may still occur west of the Great Dividing Range today (Dickman 1994). Of the non-marsupial taxa, most are rodents, which are abundant in most strata. Microchiropteran bats are represented in several strata, as are reptiles and small birds.

Table 4 presents the MNI present and % abundance per stratigraphic unit and the total taxa present. The relative abundance of selected taxa has been graphically depicted in Fig. 2. The results must be considered in light of the fact that there was considerable difference between stratigraphic units in the total number of taxa present, thus affecting comparison of percent abundance values throughout the deposit.

Taphonomy

Preservation of the bone and the observed stratigraphic variations suggest that the fauna present in the Cathedral Cave floor deposit has complex sources, and it is likely that several different agents were responsible for the accumulation of bones. In each stratigraphic unit of this deposit at least 85% of the animals present represent taxa with average body weights of less than 1.5 kg. Bones of small animals (less than 1.5 kg in body weight) are most likely to be derived from owl pellet deposits or the prey of Ghost Bats (Baird 1991), while the remains of larger animals may be accumulated by carnivores or scavengers or accumulate because the cave acts as a natural pit-trap. Analysis of the relatively intact jaw fragments of larger animals in the deposit has revealed that 88% of the macropodines present are juveniles, only three specimens representing adult individuals. Carnivores and scavengers are extremely rare in the deposit (4 jaws only), but in each case these are from adult individuals. These data indicate that large animals mainly entered the cave by falling in, their remains attracting scavengers, some of which also succumbed.

It is considered that the three phases recognised in this study represent periods in which there were different agents of accumulation or sources of the bone.

Phase 1 has the characteristics of an attritional entrance facies deposit (Baird 1991). This profile is characteristic of the distal elements of a talus cone, not markedly reworked since deposition (associated skeletal elements). Large taxa are represented by juveniles only, except for scavengers and carnivores. This is characteristic of a pitfall trap. The abundance of small mammals is consistent with accumulation due to owls and ghost bats. Within Phase 1 stratigraphic horizons are indistinct, with the exception of the unit represented by Spits 51–54 which was grey in colour, rather than the otherwise predominantly red sediments. However, the composition of the fauna varied considerably from spit to spit. For example, Spits 51–54 contained the greatest number of taxa, but fewer individuals than units above and below it (Table 4). Spits 51–54 also contained the highest fraction of bone representing large species (Fig. 3), despite the fact that it also contained the largest number of Ghost Bats.

TABLE 3

Faunal list from the floor of the Cathedral Cave, Wellington Caves, indicating presence/absence of each taxon per strtigraphic unit of the excavation

	Spits 4–5	Spits 6–10	Spits 11–15	Spits 16–19	Spits 20–23	Spits 24–28	Spits 29–33	Spits 34–38	Spits 39–42	Spits 43–48	Spits46–50	Spits 51–54	Spits 55–57
Sminthopsis crassicaudata		—										—	
Sminthopsis murina		—	—	—	—	—	—	—	—	—	—	—	—
Sminthopsis sp indet												—	
Antechinus sp cf *A. flavipes*					—	—		—	—	—	—	—	—
Phascogale tapoatafa					—		—	—	—	—		—	—
Phascogale calura												—	—
Dasyurus viverrinus	—											—	
Dasyurus geoffroii			—		—	—		—	—	—	—	—	
Dasyurus hallucatus							—	—					
Sarcophilus harrisii												—	
?*Dasyuroides* sp.			—										—
Perameles gunnii	—	—	—	—	—	—	—	—	—	—		—	—
Perameles nasuta	—	—	—	—	—	—	—	—	—	—	—	—	—
Isoodon obesulus	—	—			—	—	—	—	—	—	—	—	—
Thylacinus cynocephalus								—				a—	
Trichosurus sp.	—	—									—	—	—
Petaurus sp. cf *P. breviceps*				—	—			—	—	—	—		
Pseudocheirus sp.								—					
Acrobates pygmaeus											—	—	
Aepyprymnus rufescens	—			—	—	—					—	—	—
Bettongia sp										—			
Potorous tridactylus								—	—			—	
Macropus giganteus	—		—										
M. (Osphranter) sp.													—
M. (O) altus						#					a		
M. sp.cf. *M. (N.) agilis*						#						#	
M. sp. cf *M. (N.) dorsalis*					—					—			
M.* sp. cf. *M. (N.) rankeni										#a	#		
M. (M.) titan					#	#		#		#			
M. (M.) ferragus						#							
***Protemnodon* sp.**							—						—
Petrogale sp.					#	#				—		#	#
Thylogale sp.	—						#					—	—
Onychogale sp.												—	—
Simosthenurus oreas								—		#	#a	#	
***Diprotodon* sp.**					x								x

	Spits 4–5	Spits 6–10	Spits 11–15	Spits 16–19	Spits 20–23	Spits 24–28	Spits 29–33	Spits 34–38	Spits 39–42	Spits 43–48	Spits46–50	Spits 51–54	Spits 55–57
Thylacoleo carnifex						—	—	—		—			
Vombatus sp.		x	x		x							x	x
Phascolarctos sp											—	—	
Rodent indet (med)	—	—	—	—	—	—	—	—	—	—	—	—	—
Rodent indet (sm)	—	—		—	—	—		—	—	—	—	—	—
Mastacomys fuscus	—	—	—			—	—						—
Conilurus albipes	—	—	—	—	—	—	—	—	—	—	—	—	—
Hydromys sp.										—			
Small bats indet		—	—		—							—	—
Macroderma gigas											—	—	—
Varanus sp.					—							—	
Teliqua sp.					—	—							—
Small reptiles		—		—		—			—	—		—	
Small birds indet						—		—	—			—	—
Mollusca (snails)			—				—	—	—	—		—	

Legend: a = associated elements; # = juvenile; x = enamel fragment only; bold italics = extinct.

In Phase 2 a high degree of disturbance is suggested. The large number of limestone boulders and rocks, the highly fragmented nature of bone, and the complete absence of any associated skeletal elements, supports an hypothesis that the bones and sediments have been redeposited here. The sediments of this phase vary in the degree of cementation and include two distinct hardened “floors”, each approximately 20 cm deep. The consistent dip of the strata toward the south away from the present ‘altar’ suggests that the source of the sediments is likely to be from a point above the ‘altar’. The total number of taxa and the number of individuals represented is much lower than in Phase 1 (Table 4). The proportion of larger species is also higher than in Phase 1 (Fig. 3). The predominant presence of juveniles among the large fauna indicates that the original deposit acted as a pitfall trap for large animals. Ghost Bats are absent from the fauna of this Phase and it is likely that small mammal remains are derived from owl pellets.

There is little evidence in the upper phase (Phase 3) to suggest the probable source of inclusions. There are no large bone fragments present, and large species are represented by isolated teeth only. This differs markedly from the earlier phases and indicates that the entrance to the cave was restricted. The entrance site above the ‘altar’, suggested to have been present during Phase 2, had apparently closed by this time, as there is no evidence of large rubble or characteristics of pit-fall accumulation.

It is unlikely that this deposit was an active vadose environment at any time during the period of deposition (i.e. during the last 35,000 years), so water transport is not likely to be responsible for the accumulation of the bones. The highest terraces of the Bell River are considerably lower than the present cave entrance, and probably date from the Pliocene (Francis 1973) and the cave has never been a vadose cave, although the action of groundwater may have contributed to the secondary distribution of the elements in the deposit.

However, it is likely that level of groundwater has intermittently risen to at least the level of the present floor of Cathedral Cave over the period represented by the floor deposits (note 1954 flood level in lower chamber). This intermittent saturation and dry-

Table 4

Faunal list from Cathedral Cave, Wellington Caves, indicating the Minimum Number of Individuals (MNI) and percentage abundance of each taxon per stratographic unit

	Spits 4–5	%	Spits 6–10	%	Spits 11–15	%	Spits 16–19	%	Spits 20–23	%	Spits 24–28
Sminthopsis crassicaudata			1	1.9							
Sminthopsis murina			1	1.9	2	5.9	1	5	2	3	5
Sminthopsis sp. indet 1											
Antechinus sp. cf. *A. flavipes*									1	1.5	2
Phascogale tapoatafa									1	1.5	
Phascogale calura											
Dasyurus viverrinus	1	3.7									
Dasyurus geoffroii					1	2.9			1	1.5	1
Dasyurus hallucatus											
Sarcophilus harrisii											
?Dasyuroides sp.					1	2.9					
Perameles gunnii	1	3.7	2	3.7	1	2.9	1	5	1	1.5	2
Perameles nasuta	1	3.7	1	1.9	1	2.9	2	10	3	4.5	3
Isoodon obesulus	1	3.7	3	5.6					3	4.5	1
Thylacinus cynocephalus											
Trichosurus sp.	1	3.7	1	1.9							
Petaurus sp. cf *P. breviceps*							1	5	4	6	
Pseudocheirus sp.											
Acrobates pygmaeus											
Aepyprymnus rufescens	1	3.7					1	5	3	4.5	1
Bettongia sp											
Potorous tridactylus											
Macropus giganteus	1	3.7			1	2.9					
M. (Osphranter) sp.											
M. sp. cf. *M. (O.) altus*											1
M. sp.cf. *M. (N.) agilis*											1
M. sp. cf. *M. (N.) dorsalis*									2	3	
M. sp. cf. *M. (N.) rankeni*											
M. (M.) titan									3	4.5	1
M. (M.) ferragus											1
Protemnodon sp.											
Protemnodon brehus											
Petrogale sp.									2	3	1
Thylogale sp.	1	3.7									
Onychogale sp.											
Sthenurus sp. cf. *S. oreas*											
Diprotodon sp.											
Thylacoleo carnifex											1
Vombatus sp.			1	1.9	1	2.9			1	1.5	
Phascolarctos sp.											
Rodent indet (med)	15	55.6	38	70.4	23	67.6	12	60	27	40.3	35
Rodent indet (sm)	2	7.4	2	3.7			1	5	6	9	4
Mastacomys fuscus	1	3.7	1	1.9	1	2.9					1
Conilurus albipes	1	3.7	3	5.6	3	8.8	1	5	7	10.4	2
Hydromys sp.											
Small bats indet			1		1				1		
Macroderma gigas											
Varanus sp.									1		
Teliqua sp.									1		1
Small reptiles			1				1				1
Small birds indet											1
Total MNI Non-volant mammals	**27**		**54**		**34**		**20**		**67**		**63**
TOTAL TAXA INCLUDED	**12**		**11**		**10**		**8**		**16**		**17**

%	Spits 29–33	%	Spits 34–38	%	Spits 39–42	%	Spits 43–45	%	Spits 46–50	%	Spits 51–54	%	Spits 55–57	%
											8	4.1		
7.9	1	1.7	4	1.6	9	2.3	15	5.3	10	13.3	28	14.4	4	1.1
											3	3.1		
3.2			1	0.4	5	1.3	8	2.8	2	2.7	20	10.3	4	1.1
	1	1.7	1	0.4	2	0.5	1	0.4			2	1	1	0.3
											5	2.6	2	0.6
											1	0.5		
1.6			3	1.2	3	0.8	2	0.7	1	1.3	3	1.5		
	1	1.7	2	0.8										
											1	0.5		
													1	0.3
3.2	3	5.1	5	2	3	0.8	4	1.4			2	1	4	1.1
4.8	4	6.8	6	2.4	8	2	16	5.6	3	4	3	1.5	1	0.3
1.6	3	5.1	13	5.3	9	2.3	9	3.1	3	4	4	2.1	1	0.3
			1	0.4							2	1		
									1	1.3	2	1	1	0.3
			1	0.4	1	0.3	1	0.4	1	1.3				
			1	0.4										
									2	2.7	14	7.2		
1.6									1	1.3	1	0.5	2	0.6
							2	0.7						
			1	0.4	1	0.3					1	0.5		
													1	0.3
1.6									1	1.3				
1.6											1	0.5		
							2	0.7						
							1	0.4			1	0.5		
1.6					1	0.3							1	0.3
1.6														
	1	1.7												
													1	0.3
1.6							1	0.4			1	0.5	1	0.3
	1	1.7									2	1	1	0.3
											1	0.5	1	0.3
			1	0.4			1	0.4			1	0.5	1	0.3
													1	0.3
1.6			1	0.4	1	0.3							1	0.3
											1	0.5	1	0.3
									1	1.3	1	0.5		
55.6	37	62.7	190	77.2	308	77.4	183	63.5	6	8	21	10.8	314	85.3
6.3			5	2	19	4.8	22	7.8	42	56	57	29.2	4	1.1
1.6	5	8.5											12	3.3
3.2	2	3.4	10	4.1	28	7.1	20	6.9	1	1.3	5	2.6	6	1.6
							1	0.4						
											1		1	
											45		2	
													1	
					1		1				1			
			1		1						1		1	
.	**59**		**246**		**398**		**288**		**75**		**195**		**368**	
	11		**17**		**14**		**16**		**13**		**28**		**25**	

ing of the sediments would account for the succession of calcified 'floors' and flowstone layers encountered in the deposit. If the water level were to rise above the level of the sediments (as is likely) this would account for the levelling of the cave floor.

A high level of induration and calcification, as is observed in Phase 2 sediments, could result from a long period of stagnation of calcite-rich water — or a prolonged dry period following after a period of saturation.

SYSTEMATIC ANALYSIS

Mammalia
Marsupialia

Dasyuridae

Larger dasyurids (body weight greater than approximately 1–1.5 kg) are represented by three species of *Dasyurus* and the devil, *Sarcophilus harrisii*, all of which are scavenger / carnivores.

Species of *Dasyurus* have been identified from jaw fragments by comparison with specimens from the modern fauna in the Australian Museum. In the case of maxillary fragments, identification was assisted by the comparison of dental measurements. The ratio of protocone-parastyle length / protocone-metastyle length of M^4 distinguishes between *D. geoffroii* and *D. hallucatus*. *D. viverrinus* is distinguished by being larger than the other two species.

In Phase 1 the Western Quoll, *D. geoffroii* is represented in all units by well preserved jaws. The Eastern Quoll, *D. viverrinus*, is also represented in units 51–54 by well preserved jaws. The Devil, *Sarcophilus harrisii* is represented by a single intact right mandibular ramus. Dental measurements of this specimen place it in the range of overlap in size between the largest individuals of the modern Tasmanian population and the smallest individuals attributed to the Pleistocene species, *S. laniarius* (Dawson 1982a). Given that this specimen comes from the oldest strata of the Cathedral Cave deposit, associated with C^{14} dates of approximately 33,000 BP, it is possible that it represents the Pleistocene species, however, this diagnosis cannot be made without a larger sample.

In Phase 2 *Dasyurus geoffroii* is represented in all but one of the units in this phase. In Spits 34–38 both *D. geoffroii* and *D. hallucatus* (the Northern Quoll) are present, while a single maxillary fragment appears to represent *D. hallucatus* in Spits 29–33.

In Phase 3 large dasyurids are extremely rare, *Dasyurus viverrinus* and *D. geoffroii* being represented by a few isolated teeth only.

The most common species of Quoll represented in the Cathedral Cave deposit is *D. geoffroii*. This species was present in the western division of New South Wales at the time of European settlement, but has not been captured in New South Wales since 1857 (Dickman 1994). *D. viverrinus* has not been recorded in western New South Wales in historic times, being confined to coastal regions of south-eastern Australia and Tasmania (where it is still extant).

At least five species of dasyurid smaller than 1.5 kg body weight have been identified, all of which are extant in the modern fauna of eastern Australia. At least two species of *Sminthopsis* are represented, *S. murina* and *S. crassicaudata*, with the former being almost ubiquitous, while *S. crassicaudata* is rare, being present in two widely separated levels (Phase 1 and Phase 3) only. *Antechinus sp.* cf *A. flavipes* is present below Spit 20. *Phascogale tapoatafa* is present in Phase 1 and Phase 2, while *P. calura* is present in the lower spits of Phase 1 only.

The greater relative abundance of small dasyurids in Phase 1 compared with higher levels of the deposit is marked. Both *A. flavipes* and *S. murina* show dramatic peaks in

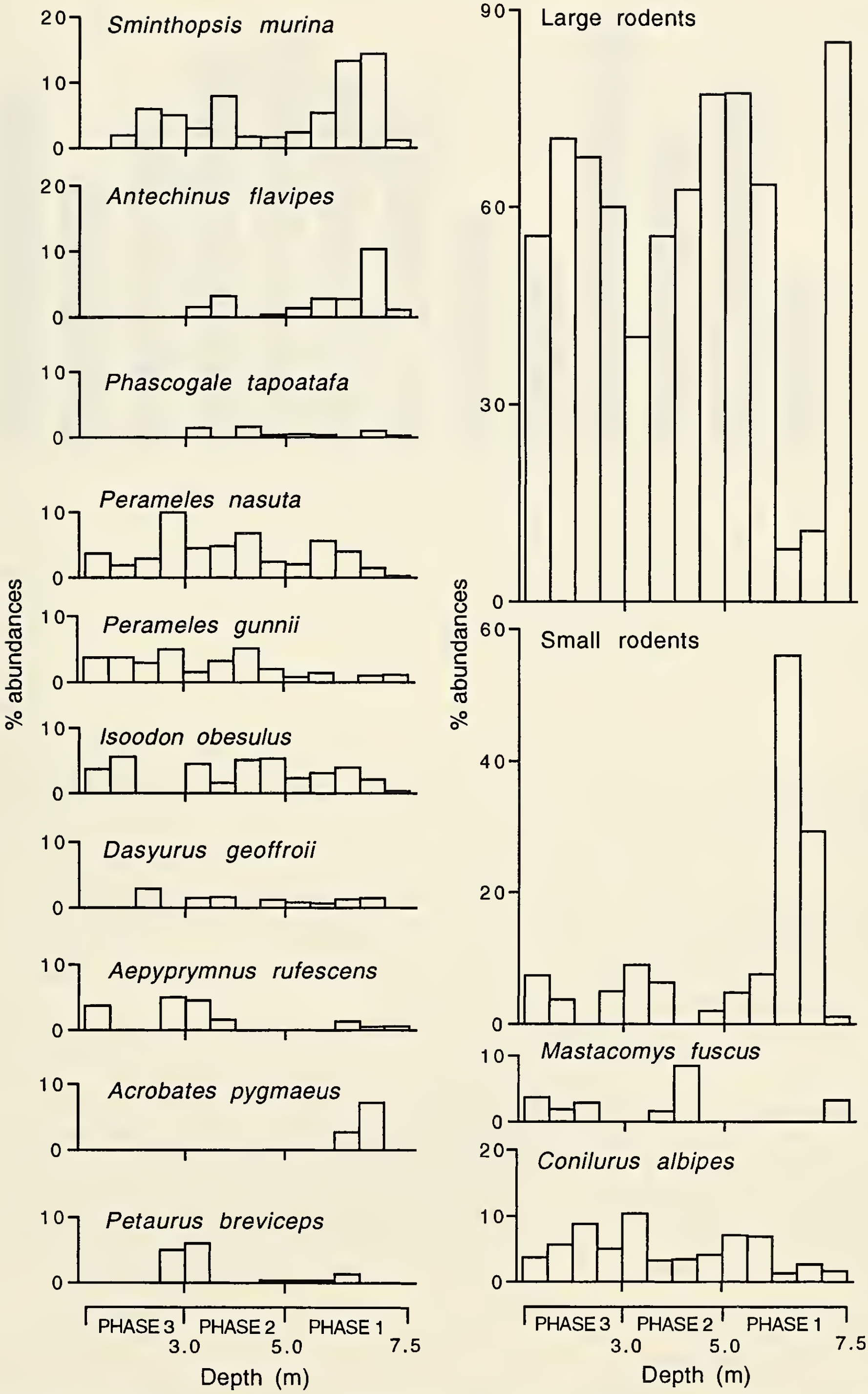

Figure 2. Relative abundance of selected mammal taxa represented in the sediments from the floor of Cathedral Cave, Wellington Caves. Data from Table 4.

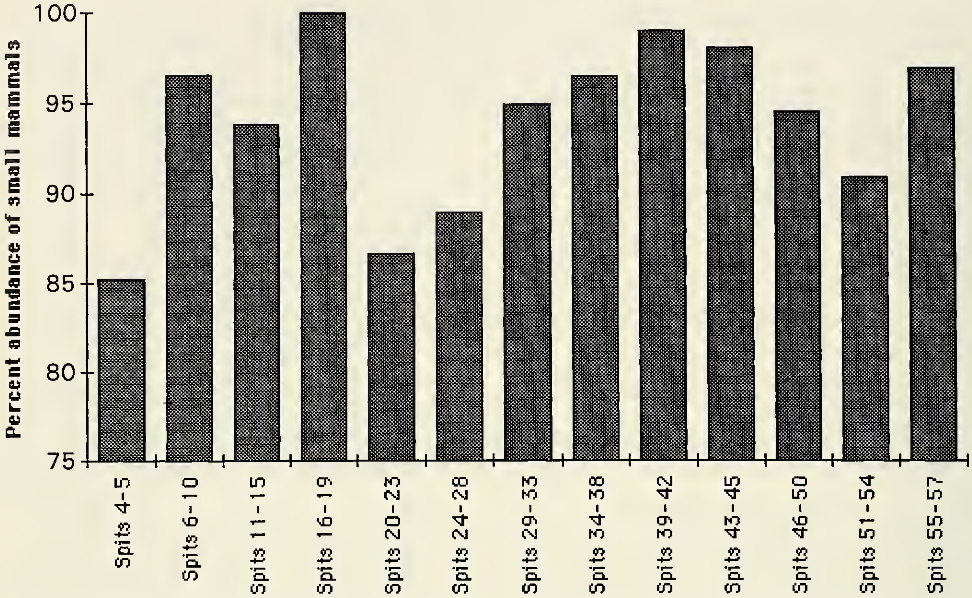

Figure 3. Relative abundance of small mammal taxa with body weight less than 1.5kg in the sediments from the floor of Cathedral Cave, Wellington Caves. Data from Table 4.

the lower units which contain the Ghost Bat, *Macroderma gigas*. These spits also contain the greatest diversity of dasyurid taxa in the deposit. In fact small dasyurids represent nearly 35% of the total number of individual animals recorded from Spits 51–54 (Table 4). While the foraging habits of the Ghost Bat most likely account for the abundance of individuals in that stratigraphic unit, other factors may account for the rich species diversity in the lower spits of Phase 1. The high diversity of small dasyurids in the 'Macroderma' spits of Phase 1 coincides with an increase in relative abundance of small rodents and a sudden sharp decrease in relative abundance of larger rodents (Table 4, Fig. 2). Detailed identification of the rodent taxa present must be undertaken before hypotheses to explain these observations can be developed.

All the species of small dasyurids identified in the Cathedral Cave deposit (with the possible exception of *Phascogale calura* and *?Dasyuroides sp.*) have ranges in the modern fauna which encompass the Wellington Valley, at least peripherally (Strahan 1983). Similarly, all species are common components of other late Pleistocene fossil faunas of eastern Australia (Lundelius 1983). With the exception of *Sminthopsis crassicaudata* and *Phascogale calura*, which have predominantly xeric habitat preferences, the species present are characteristic of woodland habitats, and none has particularly rigid vegetation or climatic limitations, although microhabitat preferences vary between species (Strahan 1983). Fox (1982) suggests, rather, that species separation is effected by body size and life strategies in small dasyurids, rather than climatic limitations.

Thylacinidae

Thylacinus cynocephalus is represented in Phase 2, Spits 34–38, by an isolated upper molar only. The only other occurrence is the presence of two left mandibular rami (adult) referable to *T. cynocephalus* in Phase 1, Spits 51–54. The dental dimensions of these specimens fall in the upper size range of modern *T. cynocephalus* from Tasmania, and within the range of Pleistocene populations from Wellington Caves and Naracoorte Caves (Dawson 1982b).

Peramelidae

Throughout the deposit peramelids are represented by jaw fragments which rarely retain the molar teeth, but isolated teeth are very common. Isolated teeth have been identified as to position in the tooth row and the estimate of minimum numbers of individuals has been based on the counts of teeth according to the method described earlier in this paper.

Isoodon obesulus is present throughout Phase 1 and Phase 2 of the deposit, increasing in relative abundance in Phase 2. In Phase 3 *I. obesulus* occurs in the uppermost units only. Two species of *Perameles* are also represented throughout the deposit. *P. nasuta* and *P. gunnii* were identified by comparison with jaws and dental characteristics of skulls from the modern fauna in the collections of the Australian Museum, Sydney, and with the descriptions and measurements given by Freedman (1967). *P. nasuta* is the most abundant peramelid taxon throughout. Both species of *Perameles* are less abundant in Phase 1 than in higher levels, and the relative abundance of *P. nasuta* over *P. gunnii* is slightly greater in Phase 1. In Phase 2 the relative abundance of both species of *Perameles* shows near parallel fluctuations. In Spits 16–19, at the base of Phase 3 both *P. nasuta* and *P. gunnii* show a sharp increase in relative abundance, at the same time that *I. obesulus* temporarily disappears from the fauna. Subsequently, in the upper units of Phase 3, *P. gunnii* is more abundant and more consistently present than *P. nasuta.* (Fig. 2).

The lower relative abundance in Phase 1 of all bandicoots, and especially of species of *Perameles*, coincides with sharp increases in the relative abundance of small dasyurid taxa and small rodents (Fig. 2). These trends probably reflect the food preferences of the Ghost Bat, *Macroderma gigas*, which is the most likely agent of accumulation of small mammals in the earliest phase of deposition.

Although these three bandicoot species have not previously been identified in the same deposit, their occurrence together is not incongruous. Gordon and Hulbert (1989) cite these species (plus *I. macroura*) as characteristic of the peramelid fauna of the coastal/sub-coastal southern humid zone, extending in part into the semi-arid zone of eastern Australia. This contrasts with the species characteristic of true semi-arid areas (including *I. auratus, P. bougainville, P. eremiana, Chaeropus* sp. and *Macrotis* sp.), none of which have been identified from the Cathedral Cave fauna.

Gordon and Hulbert (1989) note that the habitat requirements of bandicoots are extremely flexible and opportunistic, although each species may have a preferred habitat. They suggest that *P. nasuta* and *P. gunnii* may exhibit competitive exclusion in their modern distribution (e.g. in Tasmania *P. gunnii* thrives in the absence of *P. nasuta*). However, *I. obesulus* occurs with *P. gunnii* in Tasmania and with *P. nasuta* throughout their ranges in the modern mainland fauna and in most late Pleistocene faunas from eastern Australia which contain bandicoots. All three species appear to prefer open forest–grassland habitat.

This is the northernmost record of the occurrence of *P. gunnii* and this species was not recorded from the Wellington area at the time of European occupation. *P. gunnii* is known from mainland late Pleistocene faunas of South Australia (Smith 1972, Pledge 1990) and Lake Victoria in western New South Wales (Marshall 1973) as well as from the modern fauna of Victoria and Tasmania (Gordon and Hulbert 1989).

Phascolarctidae

Phascolarctos cinereus is represented in Phase 1 by a small mandibular fragment (Spits 51–54) and several isolated molars (Spits 46 and 51–54). In the modern fauna this species inhabits wooded areas and river channels throughout New South Wales, its distribution being dependent on the presence of suitable food trees rather than climatic factors.

Thylacoleonidae

Thylacoleo carnifex is represented in Phase 2 by an isolated left I_1 in Spits 24–28 and another isolated left I_1 in Spits 34–38. The species is represented in Phase 1 by a left mandibular ramus in Spits 39–42, and by an isolated I^3 in Spits 55–57. Well preserved remains of *Thylacoleo* are common in museum collections from Cathedral Cave (Dawson 1985). Many of these were collected by Henry Barnes in 1881 (Ramsay 1882), but unfortunately the original records do not include precise stratigraphic locations for the specimens.

Acrobatidae

Acrobates pygmaeus occurs in Phase 1 only, and then only in Spits 46–54, coincident with the Ghost Bat, which is most likely to be the accumulating agent. In the modern fauna, *A. pygmaeus* has a wide range of climatic tolerance, and inhabits eucalypt forest throughout the eastern coast, ranges and slopes. It is therefore unlikely that its limited distribution in the Cathedral Cave deposit is the result of climatic or vegetation factors.

Phalangeridae

Trichosurus vulpecula is represented by isolated molars in the upper spits of Phase 3. It has not been collected from the Phase 2 levels of the Cathedral Cave floor deposit, but is represented in all spits of Phase 1 below Spit 46 and by associated left and right mandibular rami from Spits 51–54. *T. vulpecula* is a generalist in its dietary preferences and inhabits a wide range of habitats. The species is common in the Wellington area today, and its absence from the Phase 2 levels of the Cathedral Cave is probably due to unknown taphonomic factors rather than indicating its absence from the fauna of the area during this phase of deposition.

Petauridae

Petaurus breviceps occurs only in the upper spits of Phase 1 (in relatively low abundance) and at the top of Phase 2 / base of Phase 3, where there is a sharp peak in abundance of this species (Table 4, Fig. 2). Occurring as they do at times of transition in the deposit, it is tempting to hypothesise that some factor related to those transitions could account for the disjunct distribution of this species in the deposit. It is most likely that they represent the prey of owls, since the species is not represented in the 'Macroderma' spits at the base of Phase 1. Given the modern range of *P. breviceps*, where it inhabits forested areas throughout the entire east coast of the continent, extending inland to the western slopes, it is unlikely that climatic limitations are responsible for the observed distribution. *P. breviceps* has been recorded from late Pleistocene faunas through the eastern margin of the continent, extending from Russenden Cave, Queensland (Archer 1978) to the Naracoorte region of South Australia (Pledge 1990)

Pseudocheiridae

Pseudocheirus sp. is extremely rare in the deposit, being represented by a single maxillary fragment at the base of Phase 2. Ringtail possums are not uncommon in other late Pleistocene faunas, and occur in the Wellington region in the modern fauna, so their virtual absence in the Cathedral Cave deposit is difficult to explain.

Potoroidae

<u>Potoroinae</u>

Three potoroine species are represented sporadically through the deposit. The most common, *Aepyprymnus rufescens*, occurs at low abundance at the base of Phase 1, peaks suddenly in the upper levels of Phase 2 and Phase 3, but is absent from the intervening levels (Table 4, Fig. 2). *Potorous tridactylus* is represented by a single mandibular fragment in each of Spits 51–54, Spits 39–42 and in Spit 38. Its distribution is thus effectively restricted to Phase 1 of the deposit. *Bettongia* sp. is represented by two isolated premolars, also in Phase 1. *Aepyprymnus rufescens* inhabits well grassed open forest, and is now almost entirely confined in its distribution to coastal and southeastern Queensland, with a relict population on the Murray River in NSW (Strahan 1983:190). A record of this species from the late Pleistocene fauna of Henscke's Cave in South Australia (Pledge 1990) suggests that its original range extended throughout mesic areas of eastern Australia, although it occurs in few fossil faunas of the late Pleistocene.

TABLE 5

Dental dimensions (mm) of *Macropus titan* from Cathedral Cave, Wellington Caves. a = approximate.

		AM F69889	AM F69890	AM F69891	AM F69892	AM F69893	AM F69894
M^2	L	14.5a					
	PW	12.6					
M^3	L	15.8					
	PW	12.8					
P_2	L			8.8	8.3	8.19.0	
	PW			6.0a	4.6	4.8	5.1
dP_3	L	11.8	10.8	11.0	10.8	11.0	
	PW		7.5	7.3a	6.9	7.0	7.1

Occlusal length I^3 = 16.0 mm (F69888)

Macropodidae

Macropodinae

Macropodine species are represented in all units of Phase 1 and Phase 2 of this deposit. However, in Phase 3 only a few isolated teeth have been recovered, most referable to *Macropus giganteus.* This undoubtedly reflects the taphonomy of the Phase 3 deposits, since it would be expected that the larger kangaroos of the modern fauna were present in the Wellington region throughout the Holocene period.

Five specimens from Phase 2 and two from Phase 1 are referable to *Macropus titan.* All jaw fragments represent juvenile individuals. Dimensions of these specimens are given in Table 5. Comparison with published data for populations of *M. titan* from Queensland and Lancefield (Bartholomai 1975, Dawson 1982c), and with data for the old collections from Wellington Caves (Dawson 1982c) indicates that the specimens all fall well within the size range of the Pleistocene species, *M. titan*, rather than the smaller *M. giganteus* .

A single mandibular fragment (juvenile) from Phase 2 (Spits 24–28) represents the giant kangaroo, *Macropus ferragus.* Dimensions of the partially erupted M_4 of F69895 are: length = 19.5mm, anterior width = 11.8mm. This species is present in the old collections from Wellington Caves and the recent collections from Bone Cave, and otherwise recorded from Pleistocene deposits of the eastern Darling Downs, Queensland, and Lake Victoria and Lake Menindee in western New South Wales (Dawson and Flannery 1985).

The Pleistocene Wallaroo, *Macropus (Osphranter) altus*, is represented by two specimens, a juvenile maxillary fragment from Phase 2 (Spits 24–28) and left and right maxillae of one adult individual from Phase 3 (Spits 46–50). Although morphologically identical to *M. robustus*, the modern wallaroo or euro, *M. (O.) altus* is considerably larger. Dental dimensions of the Cathedral Cave specimens agree in size with the holotype of *M. (O.) altus* from the eastern Darling Downs, Queensland and with a larger sample from the old collections from Wellington Caves (Dawson 1982c). A species of *M. Osphranter* is also represented by three isolated teeth, an I_1, P_3 and an upper molar, in Spits 51–54, and two isolated upper premolars in Spits 55–57.

Several species of the *Macropus* wallabies (*M. Notamacropus* spp.) (Dawson and Flannery 1985), are present in the deposit. In Phase 2 *M.* cf. *M. (N.) dorsalis* is represented by two juvenile mandibles in Spits 20–23, while a jaw of a juvenile *M.*cf *M. (N.) agilis* occurs in Spits 24–28. In Phase 1 two juvenile mandibles represent *M.* cf. *M.(N.) dorsalis* (Spits 43–45) and a single jaw fragment is referable to *M.* cf *M. (N.) agilis* (Spits 51–54). Neither of these taxa have occurred in the Wellington region in historic times, being now confined to northern Australia. However, the larger Pleistocene form of *M. (N.) agilis, M. (N.) a. siva,* is relatively common in old collections from Wellington Caves (Dawson 1985) and has been reported from Pleistocene deposits in Victoria (Marshall 1974) and New South Wales (Marshall 1973, Gorter 1977). *Macropus dorsalis* has been reported from the Pleistocene Lancefield Swamp fauna of western Victoria (Gillespie et al. 1978) but was not identified in the old collections from Wellington Caves (Dawson 1985).

A new species of large wallaby referable to *Macropus (Notamacropus)* is present in Phase 1 of the deposit. Remains similar to this species have been recorded, but not yet formally described, from the old collections from Wellington Caves (Dawson 1982c and 1985, as *Macropus rankeni* n.sp.) and from the recent collections from Bone Cave (Dawson in prep). Associated elements from Spit 43 represent the upper and lower dentition, and limb and pedal bones of a juvenile individual. The specimens from Cathedral Cave vary from the Bone Cave material in premolar morphology and in being slightly smaller, and may represent a 'dwarfed' version of the Bone Cave species. This species may have its closest affinities with *Macropus dorsalis*, but varies considerably from that species (and from all other *Notamacropus* wallabies), in being much larger, having a rel-

atively longer, more slender diastema and in premolar morphology. The elongate diastema and relatively high crowns of the molars indicate that this was a grazing animal.

Large extinct wallabies of the genus *Protemnodon* are extremely rare in the deposit, being represented by isolated teeth in Spits 29–33 and Spits 55–57 only. The teeth represented in the present collection are closest to *P. brehus* in size, but there is insufficient material for definite specific determination. Species of *Protemnodon* are well represented in the old collections from Wellington Caves but it is unlikely any of those specimens came from the Cathedral Cave (Dawson 1985).

Rock wallabies (*Petrogale* sp) are represented in Phase 1 and Phase 2 by jaw fragments of juveniles. Although *Petrogale* sp. does not occur in Phase 3 of the deposit, the Wellington region falls within the modern range of *P. penicillata*, which inhabits suitable rocky areas in sclerophyll forest of inland New South Wales (Strahan 1983:211).

The presence of species of *Thylogale* and *Onychogalea* in the lower levels of the Cathedral Cave sediments has been determined on the basis of isolated teeth (the distinctive posteriorly grooved I^3 of *Thylogale* sp and the small narrow I_1 of *Onychogalea* sp.) The presence of these taxa together in the lower levels of Phase 1 has contradictory ecological implications. *O. fraenata* inhabited shrubland and grassy woodland of the western slopes and plains last century (Strahan 1983:205), but all extant species of *Thylogale* are today confined to densely forested habitats of the east coast and ranges.

Sthenurinae

This sub-family of extinct macropodids is represented by 6 specimens from Spits below 6 metres. An isolated I^3 is the only occurrence in Phase 2 of the deposit (Spits 34–38). In Phase 1 a juvenile left maxillary fragment was found in Spits 43–45, associated left and right mandibular rami of a juvenile individual in Spits 51–54, and three isolated teeth (P_3, I_1 and M_2) in Spits 55–57. Dental dimensions of these specimens are given in Table 6. Identification of these fragments as *Simosthenurus oreas* is based on morphological comparison of the mandibular teeth (AM F69880, F69881, F69883 and F69884) with a cast (AM L1728) of the holotype, QM F2923, from the Darling Downs in Queensland, and with the descriptions of Tedford (1966). *S. oreas* is a poorly known species and the upper dentition has not previously been described. The maxillary fragment, AM 69885, has the following dental dimensions P^3 L = 15.3mm, AW = 8.0mm, PW = 9.8mm; dP^3 L = 9.5mm, AW = 8.6mm, PW = 9.8mm; M^1 L = 11.2mm, AW = 11.0mm, PW = 11.2mm. The teeth of this fragment are in the same size range as the lower molars of *S. oreas*, although size alone would not necessarily distinguish this species from similarly sized *Sthenurus andersoni* or *Simosthenurus orientalis*. The maxillary fragment AM F69885 has therefore been tentatively assigned to *S. oreas* pending comparison with more confidently assigned maxillary dentition of this species.

Three species of *Simosthenurus* and 2 species of *Sthenurus* have previously been recorded in the Old Collections from the Wellington Caves (Dawson 1985). As far as can be determined from their documentation, none of the specimens from the old collections came from Cathedral Cave. It is most likely that the three specimens of *S. oreas* in the old collections came from the Phosphate Mine, since two of the three specimens were originally part of the collections of the NSW Mining Museum, and the third bears documentation indicating it was collected in the "drives put in ..... by a Phosphate Company in search of fertiliser" (Anderson 1932). *S. oreas* is present in the new collections from Bone Cave, but is otherwise only recorded from the Pleistocene deposits of the eastern Darling Downs, and from Bingara in northern New South Wales (Tedford 1966). All species of *Sthenurus* and *Simosthenurus* represent browsing animals. Tedford (1966) has suggested that *Simosthenurus*, with its deep skull, short snout and heavily ankylosed jaws possibly browsed woodland vegetation rather than shrubs.

TABLE 6

Dimensions (mm) of the cheek teeth of specimens referable to *Simosthenurus oreas* from Cathedral Cave, Wellington Caves.

		AM F69880	AM F69882	AM F69883	AM F69884	QM F2923*
P_2	L	10.0				
	AW	6.8				
	PW	8.0				
P_3	L			14.0		14.3
	AW			6.0		6.4
	PW			8.5		—
dP_3	L	10.2				
	AW	9.0				
	PW	9.0				
M_1	L	13.2				11.8
	AW	10.5				9.8
	PW	10.7				10.0
M_2	L				14.9	14.8
	AW				11.5	11.5
	PW				11.9	11.6
I_1	Depth	12.0**	18.2			

* measurements taken from a cast (AM L1728) of the holotype.

** tooth not fully erupted.

Other marsupial taxa

Both Vombatidae and Diprotodontidae are represented in the deposit. However no analysis of these groups has been attempted, since they are represented only by small tooth fragments or fragments of dental enamel which are too incomplete to allow identification to genus level.

Placentalia

Rodentia

Rodents are by far the most abundant animals represented in the Cathedral Cave deposit, comprising in total more than 70% of the individuals present in all except three spits (Table 4). This study has not included detailed analysis of the rodent fauna, and analysis at species level has been confined to two taxa only, *Conilurus albipes* and *Mastacomys fuscus*.

C. albipes occurs throughout the deposit, at relatively low levels of abundance in Phase 1, increasing to moderately high levels in the top of Phase 2 and middle of Phase 3 (Table 4, Fig. 2). Now extinct, *C. albipes* occurred in the Wellington area early last century, and has been recorded from late Pleistocene faunas of mesic eastern Australia from Queensland (Russenden Cave, Archer 1978) to South Australia (Henscke's Cave, Pledge 1990). According to historical records it had a semi-arboreal habitat, and nested in low hollow tree branches (Strahan 1983:382).

Mastacomys fuscus has a disjunct distribution in the Cathedral Cave deposit, being present only in the base of Phase 1, and the middle spits of Phase 2 and Phase 3, respectively (Table 4, Fig. 2). *M. fuscus* is abundant in the late Pleistocene fossil faunas of the southeastern highlands such as the faunas from Jenolan Caves (Morris et al., this volume) and Wombeyan Caves (Hope 1982). It is also present in the late Pleistocene of the Naracoorte region (Victoria Cave and Henschkes Cave, Pledge 1990) and in the Seton Rock Shelter on Kangaroo Island (Hope et al. 1977). The distribution of *M. fuscus* in the modern fauna suggests a preference for cool moist climatic conditions and dense ground cover (Seebeck 1981). The occurrence of this species in the middle of Phase 2 corroborates other evidence of a cooler climate in the Wellington region at that time, but the occurrence in Phase 1 appears to be anomalous on climatic grounds because of the associated presence of the Ghost Bat (which implies a warmer climate).

Chiroptera

Microchiroptera

Unidentified microchiropteran bats are represented in the lower spits of Phase 1, where they probably formed part of the diet of the Ghost Bat. They appear to be absent from most of Phase 2, with the exception of the upper spits in the transition zone to Phase 3, where they again occur in the middle spits of this zone. This distribution possibly reflects changing entrances to the cave.

Megadermatididae

The Ghost Bat, *Macroderma gigas*, is represented in the lower levels of Phase 1, its relative abundance peaking sharply in Spits 51–54, where it comprises 45% of the individuals present (Table 4, Fig. 2). Coincident with this peak, the sediments changed from predominantly reddish to grey, and positive tests for the presence of phosphates in the sediments indicated a high proportion of guano (G. Hodge, pers comm, 1991). The data suggest that at this period the cave was most probably the home of a breeding colony of Ghost Bats.

Non-mammals.

Small reptiles and small birds are represented sparsely throughout the deposit (Table 4). A species of *Varanus* is represented at the base of Phase 1 and the top of Phase 2 only.

Of non-vertebrate remains, 11 shells of terrestrial snails (Mollusca) were found in the sediments and identified by Dr J. Stanisic of the Queensland Museum, as follows: In Phase 1 Spit 53, *Nevistitis aridorum*, Spit 43, Charopid sp.; Phase 2, Spits 30–40, *N. ari-*

dorum, Galidistes sp. *Elsothera* sp. ; Phase 3, Spit 14, *Galidistes* sp, *Glyptopupoides egregia*. With the exception of the charopid species from Phase 1 all these species are found in the area today and are quite characteristic of limestone outcrops of the central west of New South Wales. The charopid, however is typically found in wetter forests of eastern New South Wales (J. Stanisic, pers comm. 1991).

DISCUSSION

Osborne (1984) has emphasised the great difficulties involved in interpretation of the depositional events and stratigraphy of cave sediments, particularly noting the importance of recognising lateral facies change, secondary unconformities and reverse stratigraphy. A deposit such as the floor of Cathedral Cave is likely to be the result of a complex sequence of events over the period of deposition and it is to be expected that a section taken through the deposit, such as the section revealed by the present excavation, would not necessarily represent a simple depositional time line. With these considerations in mind, this attempt at interpretation of the stratigraphy and time events of this deposit has combined information from the observed sedimentary sequence with interpretation of other inclusions and the taphonomy of the bones to derive a hypothetical correlation of events. Radiocarbon dates indicate a depositional time span from approximately 35,000 BP to about 2,000 BP (in fact up to the present, since the top meter of the deposit had been too disturbed for analysis).

Taphonomic factors were of prime importance in determining the range of fauna present in the sediments. Fig. 3 indicates that in most spits of the deposit over 90% of the bones represent small mammals (<1.5 kg body weight) suggesting the main source of bone was the remains of prey of owls and, in the case of Phase 1, the Ghost Bat. The general absence of large bone (Table 1 indicates the largest bone fragment, from Phase 2, is approx 23 cm long) suggests that at no time was there a large entrance to the cave. Where large species are present they are represented by fragmentary remains of juveniles, suggesting that pitfall situations only allowed entry of small animals, or previously broken remains of larger animals. These observations could well account for the general absence of many typical late Pleistocene megafaunal species, e.g. *Diprotodon, Zygomaturus, Palorchestes, Phascolonus*, which are present in deposits of approximately the same age from nearby Cuddie Springs (Dodson et al. 1993).

Of the small mammal taxa which have been identified to species level, most could have inhabited the area at the time of first European settlement, although many would have been at the extreme of their known distributions (Strahan 1983). Further analysis of the rodents is currently being undertaken by one of us, M. L. Augee. This group is the most abundantly represented in the fauna and preliminary analysis indicates that considerable species diversity is represented. It is hoped that the rodent fauna may be of greater value in reflecting climatic or vegetation differences over the depositional period.

While differences between the three Phases primarily reflect taphonomic factors rather than climate or ecology, some trends are apparent.

In Phase 1 the presence of the Ghost Bat and the high level of species diversity indicate a warm climate with complex vegetation communities and a high level of productivity. Although the Ghost Bat is now confined to sub-tropical and monsoonal regions of Northern Australia, its fossil record indicates that it could tolerate more temperate climates (Molnar et al. 1984). However, it is suggested that they require breeding caves in which the mean temperature does not drop below 20 degrees C (Nelson 1989). With the exception of a record of two specimens from Cliefden Caves, 30 km south of Wellington (Molnar et al. 1984) this record from Cathedral Cave represents the most southern occurrence of the Ghost Bat in Eastern Australia. Owls may also have contributed to the small mammal fauna of Phase 1, and the different contributions from these two volant carni-

vores could account for some of the strange shifts in relative abundance of dasyurid and rodent taxa in the lower spits of the deposit (Fig. 2). Although Ghost Bat remains are present throughout the lower 1.5 metres of the deposit they are only abundant in a 50 cm zone of Spits 51–54. Dramatic differences in the proportion of small and larger rodents and dasyurids in these and adjacent spits, and the peak in occurrence of *Acrobates* sp. in Spits 46–54 may reflect the different feeding preferences of the Ghost Bat compared with owls, which probably became the prime contributors to the fauna after the departure of the bats. Associated C^{14} dates suggest that the period of Ghost Bat occupation of the caves ceased prior to approximately 21,000 BP, and that the peak occupations occurred prior to 30,000 BP. These data suggest that cooling climate due to the approaching glacial period may have forced the Ghost Bats to depart.

Among the larger taxa present in Phase 1, *Sthenurus oreas* and *Macropus (Notamacropus)* n. sp. represent Pleistocene species which do not occur later in Phase 2. *Phascolarctos cinereus, Sarcophilus harrisii, Phascogale calura* and unidentified species of *Bettongia, Onychogalea* and *Thylogale* are all confined to Phase 1, supporting the suggestion of complex ecological conditions supporting high productivity during that period. The presence of a species of land snail characteristic of wet forest habitats also supports a complex moister environment near the caves during the period represented by Phase 1.

Throughout Phase 2 there is a somewhat higher proportion of large mammals represented (Fig. 3), and the preservation of bone and nature of the sediments suggests a very different mode of deposition from that in Phase 1. Larger species are represented almost entirely by juveniles (Table 3) and by small highly fragmented remains. Extinct Pleistocene species are present, but rare, the grazing macropodines being the most common, with notable absence of browsing taxa (except for one jaw fragment of *Protemnodon* sp. in Spits 29–33). It is difficult to find firm evidence for climatic change during this period since the fauna continues to suggest a complex, relatively productive environment with many microhabitats being sampled. The fauna does not suggest that the Wellington area suffered undue climatic stress during the glacial maximum, the period most likely represented by Phase 2 of the deposit. The absence of *Cercartetus* sp. and of *Burramys parvus*, both of which are commonly present in faunas of similar age from nearby eastern highland regions (e.g. Jenolan Caves, Wombeyan Caves) suggest that the climate was not unduly cold.

While most of the taxa of small mammals from Phases 1 and 2 are still extant, and could have inhabited the Wellington area at the time of first settlement, the macropodine taxa, in particular, indicate significant change since late Pleistocene times. The smaller potoroid and macropodine taxa, e.g. *Aepyprymnus rufescens, Bettongia* sp., *Petrogale* sp, *Onychogale* sp., and possibly *Potorous* sp. and *Thylogale* sp. all now inhabit contracted ranges in the modern fauna but may have been represented in the Wellington area last century, although they were probably always rare (Strahan 1983, Dickman 1993, 1994). However, the larger wallabies and kangaroos (*Macropus* spp.) of the Cathedral Cave fauna are completely different from the species inhabiting the area today (i.e. *M. rufogriseus, M. robustus, M. giganteus* and *Wallabia bicolor*). *M. giganteus* is represented by isolated teeth in Phase 3 of the deposit (Holocene age), but only its 'giant' precursor, *M. (M.) titan* is present in Phase 1 and Phase 2. Similarly the Pleistocene precursor of the Euro, *M. (Osphranter) altus* is represented in Phase 1 and Phase 2.

Of the three species of *M. (Notamacropus)* ('wallabies'), present in the deposit, two, *M.* cf. *M. (N.) agilis*, and *M.* cf. *M. (N.) dorsalis*, are very close to the species now confined to northern and northeastern Australia and have not been recorded from further south in historic times. The third species of *M. (Notamacropus)* is clearly derived from a new species to be described from the early Pleistocene Bone Cave fauna of Wellington Caves (Dawson in prep.), where it forms one of the more abundant elements in that fauna. The Bone Cave species is similar to *M. (N.) dorsalis*, but is much larger and differs in other significant features.

The presence of *M. (M.) ferragus* in the upper part of Phase 2 is of interest, since this taxon appears to have been relatively common in the late Pleistocene of far western New South Wales (Marshall 1973, Merrilees 1973) and of the Pleistocene deposits of the eastern Darling Downs, Queensland (Bartholomai 1975). Its presence in Phase 2 may be an indication of more arid conditions and open grassland spreading eastwards into the Wellington area during the glacial maximum. Overall, the species of *Macropus* in the Cathedral Cave deposit represent a suite of taxa allied most closely with the fauna of northern Australian grasslands, rather than with elements more characteristic of Pleistocene faunas of Victoria or South Australia, or the macropodine fauna of the Wellington region today.

The top 2.5 to 3.0 meters of the deposit (Phase 3) evidently represents a period when the cave had a very restricted opening to the surface, insufficient to allow the entry of large bone. There is no evidence that any animals fell into the cave, nor of scavenger species. The faunal remains consist of small bones and teeth of small taxa, predominantly rodents, with some peramelids and dasyurids, probably accumulated by owls roosting in overhangs or crevices near the entrance. The bones may have washed into the cave with surface soil and debris during periods of rain, or been blown in during high winds.

Although imprecise, associated radiocarbon dates indicate that some elements of the Pleistocene 'megafauna' survived in the Wellington area at least until the glacial maximum (about 17,000 BP) and possibly later, but not into the Holocene. However, this representation is very depleted compared with the old collections from Wellington Caves, most of which are derived from the Mitchell Cave, Bone Cave and the passages of the phosphate mines (Dawson 1985). This observation is supported by new collections from the Bone Cave, yet to be described, which contain a much more diverse array of taxa than described here from Cathedral Cave, and thus support the hypothesis that the sediments in each part of the caves complex at Wellington represent different ages.

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